The role of fire and fire management in the invasion of nonnative plants in California

By Kyle E. Merriam, Tom W. McGinnis, and Jon E. Keeley

Invasive nonnative plants threaten natural resources throughout the National Park System. Nonnative plant species infest an estimated 4,600 new acres (1,863 ha) of federal land each day (National Park Service 1996), and National Park Service (NPS) policy directs resource managers to develop strategies to control or eliminate nonnative species. However, eradicating nonnative plants has proven to be difficult. One significant challenge is that fire and fire management strategies may be promoting the invasion of nonnative plants in some ecosystems. This is a serious dilemma for resource managers because fire is an important natural process and critical resource management tool on many NPS-administered lands.

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In this article we describe research being conducted by the U.S. Geological Survey, Biological Resources Division (USGS-BRD), to address the role of fire and fire management programs in the invasion of nonnative plants. We are studying how nonnative plants respond to fire and fire management strategies, and investigating the factors that influence this response. We hope this information will allow NPS resource and fire managers to develop fire management strategies that maintain the important role of fire within the National Park System, while also reducing the negative impacts of many nonnative plant species.

The link between invasive nonnative species and fire and fire management strategies

Managing invasive nonnative plants has become a priority for the National Park Service. The "Strategic Plan for Managing Invasive Nonnative Plants on National Park System Lands" (NPS 1996) recommends strategies to control nonnative plants, including prevention, public awareness, inventory and monitoring, research, and management. Many of these strategies are currently being implemented through NPS resource management plans, inventory and monitoring programs, fire monitoring programs, species-specific eradication programs, and integrated pest management plans.

One significant challenge to resource managers is that fire, an important natural process and management tool on many NPS-administered lands, may be facilitating the invasion of nonnative plant species in some areas. Studies in a number of ecosystems have found that fire often promotes nonnative plants (see D'Antonio 2000 for a review). Fire, like many disturbances, can provide openings for nonnative plant establishment, reduce competition with native species, and create favorable environmental conditions for nonnative plant species, such as elevated nutrient levels. In many cases, nonnative plant species are well adapted to fire, and can invade fire-adapted ecosystems, particularly when natural fire regimes have been altered (Keeley 2001). Once established, nonnative plants can alter fire regimes in their new habitats. They can affect the frequency and intensity of fires by altering fuel characteristics and microclimatic variables such as humidity and wind speed. For example, invasive nonnative grasses have increased fire intensity and frequency in a number of ecosystems throughout the world by increasing the amount of continuous fine fuels across formerly patchy landscapes (D'Antonio and Vitousek 1992). In the Great Basin, fire return intervals have decreased from 30 to 100 years to 5 years in some areas (Whisenant 1990). Native woody species in a variety of habitats cannot tolerate intense and frequent fires, and as a result many areas have been transformed from diverse native woodlands and shrublands into homogeneous exotic grasslands.

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Prescribed burning has been suggested as a means to control both perennial and annual nonnative plants in some areas. However, the frequency, intensity, and timing of the prescribed burn must be carefully controlled to exploit a vulnerable life history stage of the target species. For example, burning prior to seed release can temporarily reduce the abundance of nonnative annuals. However, this approach may also negatively affect native annual plants. Prescribed fire may inhibit one nonnative species while promoting another. For example, in one study in the Sierra Nevada foothills of California, prescribed burning was effective at reducing the dominance of nonnative grasses, but increased the dominance of nonnative forbs (Parsons and Stohlgren 1989). Resource managers may have to weigh the benefits of controlling one plant species through prescribed burning against the costs of damaging a native plant species or promoting another nonnative plant species. In areas where nonnative plant species have a well-established seed bank, fire is generally an ineffective means of control.

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Many fire management plans include fuel reduction strategies such as thinning and the construction of fuel breaks. The role of fuel breaks in promoting nonnative plants has not been specifically studied. However, fuel breaks share many common characteristics with roads, which have been extensively linked with nonnative plant invasion (D'Antonio et al. 1999). Fuel manipulations create disturbance by removing vegetation, opening forest canopies, disturbing soils, and changing hydrologic conditions, factors that generally promote nonnative plants (D'Antonio et al. 1999). Equipment used to construct fuel breaks or to thin forests may transport the seeds of nonnative plant species into areas where they were not formerly present. The effect of localized fuel treatments on nonnative plant invasions can be profound. The establishment of nonnative plants in fuel breaks may provide an exotic seed source in close proximity to remote wildland areas. These wildland areas are then more susceptible to invasion, particularly following disturbances such as natural or prescribed fires (D'Antonio 2000). Nonnative plant invasion in fuel manipulation zones could also increase fire frequencies and alter fire intensity to the detriment of native plant communities (Keeley 2001).

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Maintaining fire and fire management while decreasing the risk of invasive nonnative plant species

Fire is an important natural process and resource management tool on many NPS-administered lands. Fire management strategies include wildland fire use, prescribed burning, and fire suppression. After many decades of fire exclusion, the National Park Service has recognized the importance of fire to maintain native plant and animal communities and ecological processes in many ecosystems. The Park Service has developed clear recommendations and guidelines for the use of fire within the National Park System, including the Federal Wildland Fire Management Policy and Program Review (Glickman and Babbitt 1995), Director's Order 18: Wildland Fire Management, and Reference Manual 18: Wildland Fire Management (NPS 2003). These documents outline the important uses of fire and fire management in the National Park System, including "restoring, mimicking, or replacing the ecological influences of natural fire, maintaining historic scenes, reducing hazardous fuels, eliminating exotic/alien species, disposal of vegetative waste and debris, and preserving endangered species"(NPS 2003). With this guidance, numerous NPS units have developed fire management programs based upon resource management objectives, including maintaining the natural role of fire based on historical fire regimes.

Policy of the National Park Service also includes fuels management as an important component of fire management. The Federal Wildland Fire Management Policy and Program Review (Glickman and Babbitt 1995) and the National Fire Plan (2001a) target fuels reduction as a primary goal. In 2002, 2.25 million acres (0.91 million ha) of federal land managed by the Department of the Interior and the USDA Forest Service were treated to reduce hazardous fuels (National Fire Plan 2002). The National Fire Plan's 10-Year Comprehensive Strategy (National Fire Plan 2001b) calls for increases in current levels of fuel treatment, and many NPS units are currently developing large-scale fuel treatment plans, particularly at the wildland and urban interface.

Developing alternative strategies

National Park Service resource and fire managers must weigh the benefits of fire and fire management strategies against the risks of promoting invasive nonnative plant species. Collecting data on how fire management practices promote nonnative plant invasion may provide information necessary to modify existing fire management practices. Policy and guidelines of the National Park Service encourage evaluation and modification of management strategies through an adaptive management approach. For example, the Strategic Plan for Managing Invasive Nonnative Plants (NPS 1996) describes how "Working together, scientists and resource managers must gather sound scientific information, use the information to develop management techniques, monitor the results of the management activities, determine if clearly stated objectives are being met, and modify activities as indicated."

In order to develop information necessary to evaluate fire management strategies, the USGS-BRD Sequoia and Kings Canyon Research Station is conducting research on the role of fire and fire management strategies in the invasion of nonnative plants. One study investigates the role of prescribed fire in the invasion of cheatgrass into Kings Canyon National Park. Another study addresses the role of fuels treatments in the invasion of nonnative plant species throughout California. We hope these studies will provide information that will assist resource managers in modifying existing fire management programs so they will continue to meet their objectives while minimizing the threat of nonnative plant invasion.

USGS study of fire and cheatgrass in Kings Canyon National Park

In the 1980s the National Park Service introduced prescribed burning into ponderosa pine and mixed-conifer forests of Cedar Grove, a large glacially carved canyon in the west end of Kings Canyon National Park, California. Within two decades, nearly all of the Cedar Grove forests had been burned with low intensity surface fires. This ended an unnaturally long period of more than a century of fire exclusion from these forests and was an important step towards restoring a presettlement fire regime. However, during this long period of fire exclusion, a particularly aggressive nonnative annual grass (cheatgrass, *Bromus tectorum*) had established in the Cedar Grove area. Prior to the reintroduction of fire, cheatgrass was most common in disturbance corridors such as trails, roads, and areas of intensive stock use. Unfortunately, these disturbance corridors served as ideal fire lines for prescribed burning, and following prescribed burns, cheatgrass rapidly spread throughout Cedar Grove into large and small fire-caused openings as well as other disturbed sites in the canyon. Alarm over this invasion was sufficient enough to halt indefinitely all further burning in these forests.

In order to investigate the spread of cheatgrass in Kings Canyon National Park, the U.S. Geological Survey has established a research program to better understand the causal basis for cheatgrass invasion and how fire management practices may affect this invasion process. Through funding by the Joint Fire Sciences Program, and with the cooperation of the Sequoia and Kings Canyon National Parks' fire management program, we initiated an intensive experiment to evaluate prescription burning impacts on cheatgrass spread (fig. 1). In this experiment we have manipulated fuel loads, season of burn, shade, and plant nutrients in order to better understand which fire-related variables promote this species. To investigate the effect of season of burn, we conducted prescribed burns after cheatgrass seeds were dispersed in the fall and prior to

Figure 1. A USGS researcher records fire behavior as a prescribed burn moves through a cheatgrass plot in Kings Canyon National Park. A data-logger records above- and below-ground temperatures from thermocouples. USGS PHOTO BY TOM MCGINNIS

cheatgrass seed dispersal in the spring. In order to investigate how fire temperatures affect the seed bank and nutrients in the soil, we continuously measured temperatures above and below ground during prescription burning, using electronic thermometers, or thermocouples. We hope this information will indicate which variables most strongly influence the invasion of cheatgrass, and allow us to provide data to resource and fire managers that will be useful in developing fire management strategies that do not promote the spread of this invasive species, and that may help to control it. Ultimately it must be recognized that "natural" presettlement fire regimes occurred in a landscape lacking the current pallet of alien species. It may turn out that managers will be forced to alter fire restoration objectives in order to accommodate this new landscape.

USGS study of pre-fire fuel manipulation and nonnative plant species

Another study being conducted by the USGS-BRD Sequoia and Kings Canyon Research Station and funded through the Joint Fire Sciences Program addresses the role of fuel breaks in promoting the invasion of nonnative plants. Fuel breaks are generally constructed to change fire behavior, to provide firefighter access, as a starting point for indirect attack on wildland fires, or to contain prescribed fires (Agee et al. 2000). We define fuel breaks as any area specifically treated to reduce fuels, including linear, cleared features, or large, thinned areas with some canopy cover left intact (shaded fuel breaks). Many federal agencies are currently developing large-scale fuels management programs to reduce the spread of unwanted wildland fires, particularly at the wildland and urban interface (National Fire Plan 2001a).

To examine the role of fuel breaks in promoting invasion by nonnative plant species, we are investigating fuel breaks in a range of plant community types across California, including chaparral, mixed woodlands, and coniferous forests. So far we have visited 10 fuel breaks, including several constructed along the wildland and urban interface. We investigated fuel breaks on NPS lands, in addition to fuel breaks constructed by the USDA Forest Service. Our preliminary data indicate that the relative number, cover, and density of nonnative plant species are generally higher on the fuel break than in the surrounding wildlands (fig. 2). However, each site varied greatly in the number and relative dominance of nonnative plants. One site we investigated near Lake Tahoe contained no nonnative plant species, while other sites had as many as 19 nonnative plant species, representing 88% of all plant species encountered on the fuel break. This site-to-site variability suggests that individual site conditions, including environmental and human-caused factors, play an important role in the ability of nonnative plants to invade. We will be investigating additional fuel breaks during the next two years to determine which factors influence invasibility.

Management implications

Our data should indicate what types of fuel breaks are most likely to promote nonnative plants. For example, studies have shown that canopy cover is an important factor in the establishment of nonnative plant species (Rejmanek 1989). We are measuring canopy cover at each of our sites, and we have negatively correlated canopy cover with nonnative plant presence. By determining the relationship between canopy cover and nonnative plant presence in fuel breaks, we hope to develop recommendations for canopy cover prescriptions within fuel breaks

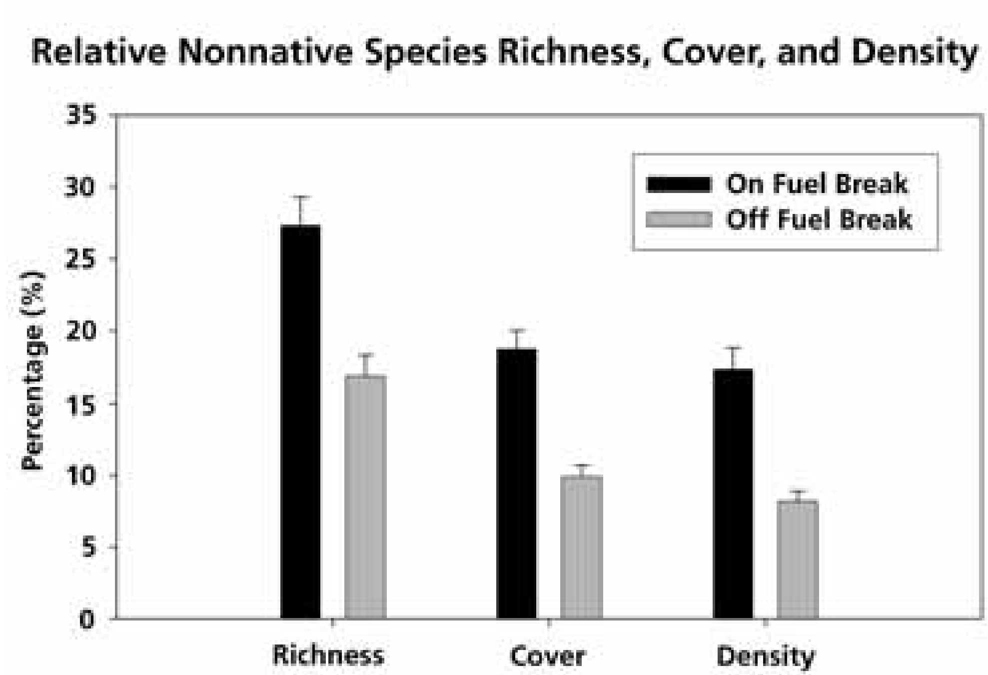

Figure 2. The USGS research compared the relative nonnative species richness, cover, and density on and off a fuel break and found them all to be significantly higher on the fuel break than off it in the surrounding wildlands. A statistical method known as an Analysis of Variance (ANOVA) was used to determine if plots were different on fuel breaks based on the amount of variation present in the data. According to the ANOVA, the probability was less than 0.001 that the differences in nonnative richness, cover, and density on fuel breaks had occurred by chance.

that minimize the threat of nonnative plant invasion.

Fuel break construction and maintenance methods may also influence the invasion of nonnative plants. Some fuel breaks are constructed and maintained primarily through mechanical means (fig. 3), while others may be cleared by hand or through the use of prescribed burning. Many fuel breaks are constructed and maintained using a combination of mechanical clearing and prescribed burning (fig. 4), and in some areas herbicide application is part of the maintenance prescription. In some areas fuel breaks are being constructed through on-site chipping or mastication of fuels. These chipped fuels remain on the ground or are removed by prescribed fire. On-site chipping of fuels possibly reduces germination of nonnative plants. Our data should indicate which of these construction methods and maintenance regimes is least likely to promote nonnative plant invasion.

Much of our analysis will investigate the importance of landscape-level factors, such as proximity to roads and other fuel breaks. Our results should provide fire and resource managers with information necessary to plan the strategic placement of fuel breaks such that the risk of nonnative plant invasion is minimized.

Figure 3. Researchers examine a fire line constructed by bulldozer in the Shasta Trinity National Forest, near Weaverville, California. USGS PHOTO BY KYLE MERRIAM

Figure 4. This shaded fuel break, called a defensible fuel profile zone, is located in Plumas National Forest, California, and has been mechanically thinned and burned with a prescribed fire. USGS PHOTO BY KYLE MERRIAM

Conclusion

The mission of the USGS Biological Resources Division is to work with others to provide the scientific understanding and technologies needed to support the sound management and conservation of our nation's biological resources. Our research on the role of fire and fire management strategies in the invasion of nonnative plant species is intended to provide fire and resource managers with information to assist them in addressing this complex issue through the development of fire management strategies that reduce nonnative plant invasions.

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